

# THE TRICKY GALACTIC CLUSTER NGC2420

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**ABSTRACT.** We discuss the CM diagram of the galactic cluster NGC2420 to the light of current theoretical predictions. By relying on the most recent updating of the physical input, one finds too luminous theoretical He burning stars together with the evidence for a misfitting of the lower portion of the MS. Moreover one finds two well known overshooting signatures, as given by i) the large extension of the “hook” preceding the overall contraction gap, and ii) the scarcity of stars just at the end of the gap. We show that the overluminosity of He burning stars appears as a constant prediction of models based on updated physics, whereas alternative assumptions about the Equation of State can account for the MS fitting. Moreover, due to the scarce statistical significance of the observational sample, one finds that overshooting signatures can be present also in canonical (without overshooting) predictions. We conclude that, unfortunately, NGC2420 does not keep the promise to be of help in constraining the actual dimensions of convective cores in H burning MS stars, suggesting in the meantime that using clumping He burning stars as theoretical standard candle is at least a risky procedure. In this context the need for firmer constraints about the reddening of galactic clusters is shortly discussed.

## 1. Introduction

The beautiful CM diagram presented in 1990 by Anthony-Twarog et al. for the intermediate age open cluster NGC2420 has been in the last ten years a favourite target for all the people concerned with the evolution of low to intermediate mass stars. The occasion for revisiting this cluster has been given to us by the recent paper by Pols et al. (1998, hereinafter P98), who presented new evolutionary tracks carefully discussing the fit of a selected (and well chosen) sample of galactic clusters. As discussed in that paper, NGC2420 seems to give a good chance to put firm constraints on the efficiency of the mechanism of core overshooting. Owing to the relevance of such an issue, we decided to go deep into the matter, hoping eventually to settle down such a long debated argument. However, as we will discuss in the following, the situation is far from being assessed.

## 2. Isochrone fitting

According to Anthony-Twarog et al. (1990) metallicity estimates give for the cluster  $[\text{Fe}/\text{H}] = -0.35 \pm 0.10$ , but with evaluations reaching  $[\text{Fe}/\text{H}] = -0.6$  (Canterna et al. 1986). Following P98, we will assume  $Z = 0.007$  ( $[\text{Fe}/\text{H}] = -0.4$ ). By taking  $Y = 0.23$  for old metal poor stars and accounting for a galactic He enrichment law as given by  $\Delta Y / \Delta Z \approx 2.4$

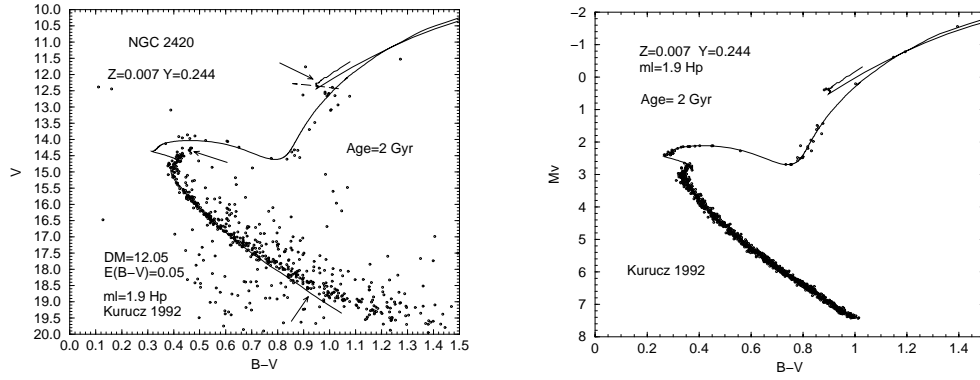


Fig. 1. Left panel: Fit of the cluster with the 2.0 Gyr theoretical isochrone; the arrows mark the regions where the fitting is not good. The dashed line indicates the variation of the visual magnitude of the He clump when its temperature is varied to reach the observational color of He burning stars, see text. Right panel: The same 2.0 Gyr isochrone with overimposed the corresponding synthetic CM diagram without binaries.

(see e.g. Pagel & Portinari 1998) we obtain for the cluster  $Y=0.244$ . The adopted evolutionary code and physical inputs are the same as in Cassisi et al. (1998); in particular to start our investigation we adopted the OPAL EOS (Rogers et al. 1996).

Figure 1 (left panel) shows the best fitting of our isochrone to the cluster CM diagram, as obtained by using colour-temperature relations from Kurucz (1992) and by adopting for the cluster just the same reddening and the same age as in P98. As a result, we found that a best fitting is indeed achieved, with only a small difference in the cluster distance modulus ( $DM = 12.05$  against 11.95 in P98), which appears the natural result of the differences between the two MS luminosities already discussed in Prada Moroni et al. (2000). The impressive agreement between the two theoretical scenarios can obviously taken as an evidence that neither differences in the adopted input physics nor in the color-temperature relation play a relevant role in the predicted models. As already discussed by P98, one finds that theoretical He burning stars appear too luminous, by about 0.3 mag. However, in both theoretical isochrones one can also find the evidence for a misfitting of the lower portion of the MS, with too blue theoretical models. As well known, low masses MS stars are less and less affected by the efficiency of the external convection, thus it appears difficult to reconcile theory and observation only by tuning the mixing length parameter (see e.g. Castellani et al. 1999). To discuss overshooting, Figure 1 (right panel) depicts theoretical expectations, showing a synthetic cluster as obtained by randomly populating the isochrone till obtaining 24 stars brighter than  $M_V = 2.1$ , as observed. Comparison with the CM diagram in Fig. 1 (left panel) discloses in the observational data the two well known overshooting signatures, namely: i) the larger extension of the “hook” preceding the overall contraction gap, and ii) the lack of the concentration of stars just at the end of the gap, expected under canonical assumptions.

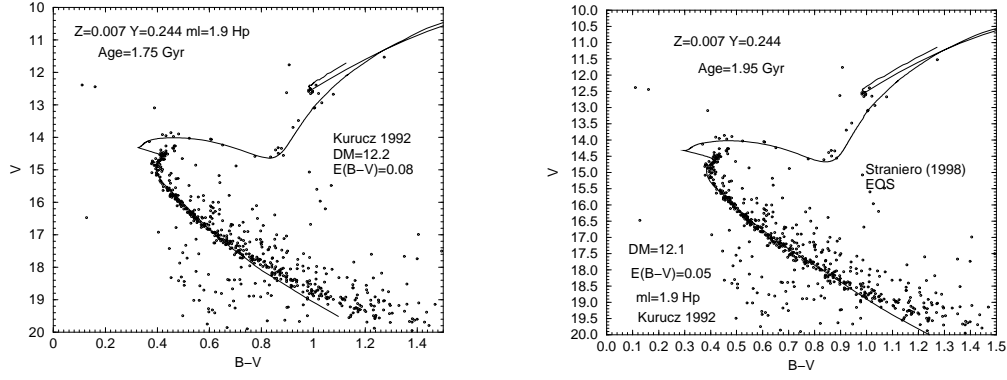


Fig. 2. Left panel: Best fit of the cluster with 1.75 Gyr theoretical isochrone with OPAL EOS. Right panel: Best fit of the cluster with 1.95 Gyr theoretical isochrone with Straniero (1998) EOS

However, the fitting can be improved by increasing the reddening thus driving a larger evaluation of the cluster distance modulus, alleviating the overluminosity of predicted He burning stars. This is shown in Fig. 2 (left panel), which reports our best fitting as obtained for  $E(B-V) = 0.08$ . Moreover, increasing the reddening the Turn Off becomes bluer and the cluster younger, increasing the extension of the hook (see Fig. 1 for comparison), also alleviating this discrepancy. However, no one of these discrepancies is completely resolved, nor increasing the reddening helps to solve the disagreement for the lower MS. Concerning the problem of the MS fitting, one has to conclude that either the color temperature relation or the MS models are wrong, if not both. To explore theoretical models, we repeated the previous computations but adopting the alternative Equation of State presented by Straniero (1998). As shown in Fig. 2 (right panel), we found that theoretical and observational MSs appear now in reasonable agreement, disclosing that a solution to this problem already exists within the currently available theoretical scenarios. On the contrary, the replacement of Kurucz (1992) colour-temperature relations with the most recent and widely adopted semiempirical relations by Alonso et al. (1996, 1999) cannot solve the discrepancy between the theoretical and the observational low MS. In this case, in fact, one obtains a shift toward bluer MS colours, which would affect (increase) the reddening evaluations by about 0.05 mag, but not the MS slope.

### 3. The tricky binaries

According to the discussion in the previous section, one is left with the evidence of a small overluminosity of He burning stars and with two clear signatures for the efficiency of overshooting. As a matter of fact, numerical experiments confirmed that allowing for a moderate overshooting (of the order of 0.1 pressure scale height,  $H_p$ ) our theoretical isochrone would match much better the observed diagram. However, in a previous paper (Castellani et al. 1999) we have already drawn the attention on the evidence

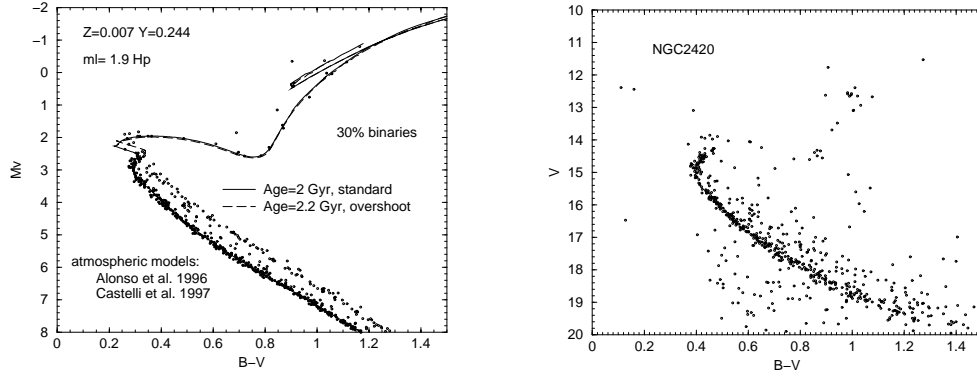


Fig. 3. Left panel: solid line: theoretical standard (without overshoot) 2.0 Gyr isochrone with Straniero (1998) EOS ( $Z=0.007$   $Y=0.244$ ) with overimposed the corresponding synthetic CM diagram including 30% of binaries; dashed line: theoretical 2.2 Gyr isochrone with Straniero (1998) EOS and mild overshooting ( $l_{ov} = 0.1H_p$ ). Right panel: NGC2420 CM diagram by Anthony-Twarog et al. 1990. Observational data are not dereddened.

that binaries stars, as obviously present in the cluster, may mimike overshooting by extending the hook above its natural maximum luminosity. Thus we tested the effects of binarity again by producing synthetic clusters from canonical (without overshooting) models but allowing for 30% binaries (as obtained by a rough estimate from the CM diagram) according to the following distribution of mass ratio: 50% between 0.8 and 1, 30% between 0.6 and 0.8, the remaining 20% totally random (Tornambè A., private communication).

As predicted, and as shown in Fig. 3, left panel, binaries tend to extend the hook, producing in this region a CM diagram which appears in better agreement with overshooting computations. However, and to our surprise, one also finds that in a good percentage of the random clusters, namely of the order of about 50%, the predicted “post-gap” distribution sensitively deviates from canonical expectations, approaching the one actually observed in the cluster (see, e.g., Fig. 3, right panel). The reason for such an occurrence is easily found in the scarce statistical significance of the number of luminous stars together with the non negligible contribution of binaries. As a result, we conclude that NGC2420 is actually failing to give the expected constraints about the overshooting efficiency. As a matter of the fact, both the discussed canonical and mild overshooting cases appear acceptable. However, numerical simulations seems to suggest that an overshooting as large as  $0.25 H_p$  would depopulate too much the red part of the subgiant branch.

#### 4. Conclusions

According to the previous sections, one finds that three out of the four theoretical misfitting of the cluster CM diagram can be accounted for within current evolutionary scenarios. On the contrary, no assumption appears able to reconcile the predicted luminosity of

He burning stars with observation. To explore all the possibilities one may guess that a given amount of mass loss could account for this discrepancy. One generally assumes that mass loss occurs in the advanced phase of H shell burning, so that the internal structure of the He burning star is not affected by such an occurrence, which only decreases the amount of envelope surrounding the central He core. Under this assumption, the effect of mass loss on He burning models can be easily computed by simply decreasing the envelope of the constant-mass model. Numerical simulations shows that to reach the agreement between theory and observation for the clump luminosity one needs to decrease the He burning mass from the standard value of  $\approx 1.5 M_{\odot}$  to  $1.0 M_{\odot}$ . This very high amount of mass loss seems very unlikely to us.

At present time the discrepancy between theory and observation in the luminosity of He burning stars with degenerate RGB progenitors it is not a surprising result; it appears as a constant prediction of models based on updated physics (see e.g. P98, Castellani et al. 2000), whereas similar suggestions for the overluminosity of theoretical models have been also derived from the pulsational properties of RR Lyrae (see e.g. Caputo et al. 2000). We conclude that using clumping He burning stars as theoretical standard candles, as we did (Castellani et al. 1999), is at least a risky procedure. We note that in the above quoted work, one could recognize a signature of the overluminosity in the need of assuming rather large reddenings for all the clusters. In this context, it follows that firm constraints about the reddening of galactic clusters will help in solving this problem.

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